

Status of SUSY Searches

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Searches for supersymmetric particles at LEP are first reviewed, with some emphasis on the mass limit for the lightest neutralino. The framework is the MSSM with R-parity conservation, with brief excursions towards mSUGRA and GMSB. Next, recent results obtained in the Run II of the Tevatron are presented.

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1 Introduction

Let me first start with what this talk will not be:

- an introduction to supersymmetry. First of all you are all experts in the field, and second we just attended an excellent introductory presentation[1];
- a discussion of the cosmological aspects, mostly due to my inability;
- a comprehensive review because of the limited amount of time available.

This discussion will rather focus on:

- the LEP legacy, with minimal experimental details, because the LEP results often remain the most constraining at this point;
- recent results from the Run II of the Tevatron, which is currently the most powerful collider in operation. At the Tevatron, proton-antiproton collisions take place at a center-of-mass energy of 1.96 TeV, and the instantaneous luminosity recently reached the $10^{32} \text{cm}^{-2} \text{s}^{-1}$ level.

The frameworks in which these results will be presented are:

- most of the time “standard SUSY”. This means the MSSM, often with some generic unification constraints (essentially for slepton or gaugino SUSY-breaking masses) at the scale of grand unification (GUT), and with the assumption that the lightest supersymmetric particle (LSP) is the lightest neutralino χ . Occasionally, the model considered will be even more constrained in the form of minimal supergravity (mSUGRA);
- in a few instances gauge mediated supersymmetry breaking (GMSB), which offers clean and simple signatures, in its minimal version;

- with R-parity conservation. Again, this is mostly due to lack of time in view of the large number of equally acceptable scenarios, and also partly because of a personal prejudice having to do with the absence of dark matter in R-parity violating models. (Here I have to seek forgiveness from my HERA colleagues.)

At LEP, all supersymmetric particles, except for the gluinos, are produced in a rather democratic fashion via electroweak interactions, up to mass effects. Since pair production of the LSP is not directly detectable, the search is naturally directed towards the next-to-lightest supersymmetric particles (NLSP's). The results can often be presented in a model independent, or at least moderately dependent, way. Results from various channels can furthermore be combined within some specific theoretical framework to derive additional constraints, of which the most celebrated one is the LSP-mass lower limit.

At the Tevatron, colored particles (i.e., squarks and gluinos) are expected to be produced with large cross sections via strong interactions. The resulting final states consisting mostly of jets and missing transverse energy however suffer from large backgrounds from standard multijet production. The electroweak production of charginos and neutralinos has a much lower cross section, but clean final states such as trileptons and missing transverse energy are considerably easier to discriminate from standard model backgrounds. Finally, in contrast to the situation at LEP, a model independent presentation of the results is usually unavailable because it is highly impractical to provide one which would be both transparent and meaningful.

All limits (unfortunately...) quoted in the following are given at 95% confidence level.

2 Standard SUSY: the LEP legacy

Because this is probably the simplest channel, both theoretically and experimentally, among those which have been analysed at LEP, let us begin with the search for smuon pair production, which proceeds only through γ/Z exchange in the s -channel. It is assumed that it is the supersymmetric partner $\tilde{\mu}_R$ of the right-handed muon which is the lighter of the two smuons, an assumption which is valid in models involving the unification of SUSY-breaking masses and which is conservative in terms of production cross section. The only parameter which is needed to calculate this cross section is the smuon mass. If the smuon is furthermore assumed to be the NLSP, the only decay channel available is $\tilde{\mu}_R \rightarrow \mu\chi$, and the only additional parameter involved is the LSP mass m_χ . The final state consists in a pair of acoplanar muons, and the main background, from $WW \rightarrow \mu\nu\mu\nu$, is well under control. The search result obtained by the four LEP experiments combined is shown in Fig. 1(left) [2]; the gap along the diagonal is due to the softness of the muons when the $\tilde{\mu} - \chi$ mass difference is very small. With the additional condition of gaugino mass unification, the assumption that the smuon is the NLSP can be relaxed, and the effect of cascade decays such as $\tilde{\mu} \rightarrow \mu\chi'$ with $\chi' \rightarrow \gamma\chi$ can be incorporated. These cascade decays occur only at small values of m_χ , for which the smuon mass limit of almost 100 GeV is slightly degraded.

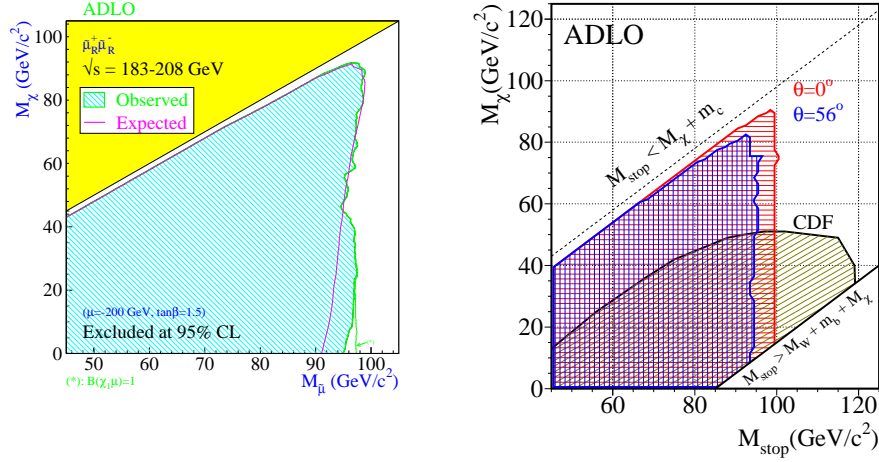


Fig. 1. Domains excluded by the four LEP experiments: in the $(m_{\tilde{\mu}}, m_{\chi})$ plane (left), where the reduced sensitivity due to cascade decays is visible for low values of m_{χ} ; in the $(m_{\tilde{t}}, m_{\chi})$ plane (right), for $\tilde{t} \rightarrow c\chi$ prompt decays, where the innermost and outermost contours correspond to vanishing and maximum $Z\tilde{t}\tilde{t}$ couplings, and where the domain excluded by CDF at Run I is also shown.

The interpretation of the other slepton searches involves some degree of model dependence. For staus, the mass eigenstates may significantly differ from the electroweak eigenstates (in a way similar to stops, as discussed further down), and the most conservative results are quoted for the case where the coupling of the lighter stau to the Z vanishes [2]. For selectrons, the situation is complicated by the contribution of t -channel neutralino exchange to the pair production process. The interference is however typically constructive, and the mass limits for selectrons are therefore slightly higher than for smuons [2].

The mass matrix of scalar leptons or quarks contains off-diagonal terms which are proportional to the standard lepton or quark mass. Because of the large top-quark mass, it can be expected that mixing is important in the stop sector, and therefore that the lighter stop could be substantially lighter than generic squarks (and similarly, the lighter stau could be lighter than the other sleptons). This effect may even be enhanced in models with squark mass unification by the effect of the negative contribution of the large top-quark Yukawa coupling in the renormalization group equations for the stop masses. Although generic squarks are more efficiently searched at the Tevatron, well beyond the kinematic reach of LEP, the lighter stop might still be light enough to be accessible at LEP. Given the chargino mass limits (discussed further down), this stop would decay according to $\tilde{t} \rightarrow c\chi$. Since

this is a loop decay, the hadronization time may be similar to or shorter than the decay time, and dedicated generators had to be set up to simulate the creation of stop-hadrons and their interaction with the detector. All possible topologies arising from stop pair production have been analysed, ranging from acoplanar jets for short stop-hadron lifetimes, to pairs of heavy charged or neutral particles for very long lifetimes, where the stop-hadron lifetime depends essentially on the $\tilde{t} - \chi$ mass difference [3]. For stop masses less than about 100 GeV, the domain excluded at the Tevatron is extended for $\tilde{t} - \chi$ mass differences smaller than ~ 30 GeV, as shown in Fig. 1(right) [2].

Charginos can be pair produced by s -channel γ/Z exchange, and by t -channel exchange of the electronic sneutrino, with a destructive interference between the two channels. Similarly, pair or associated production of neutralinos involves Z and selectron exchanges, but now with a constructive interference. The analysis is greatly simplified under the assumption that all sleptons are very heavy. In such a case, the production cross section for charginos depends on the three parameters entering the chargino mass matrix: the SUSY-breaking gaugino mass M_2 , the higgsino mass term μ , and $\tan\beta$, the ratio of the vacuum expectation values of the two Higgs fields. For neutralinos, an additional gaugino mass term is needed, M_1 , with a value most commonly dictated by the unification condition ($M_1 \sim M_2/2$).

For heavy sleptons, the decay processes are $\chi^+ \rightarrow \chi W^*$ and $\chi' \rightarrow \chi Z^*$, so that the final states simply reflect the W and Z decay modes. All relevant topologies have been analysed: multijets, acoplanar jets or leptons, leptons + jets, all with missing energy carried away by the two LSP's. In the end, the kinematic limit of almost 104 GeV is essentially reached for chargino pair production [2]. For any fixed $\tan\beta$, this result can be turned into an exclusion domain in the (M_2, μ) plane. This domain is slightly extended by the searches for neutralinos, which translates in turn into chargino exclusions indirectly extended by up to 10 GeV (for low negative values of μ and small $\tan\beta$). The above mentioned chargino searches loose sensitivity for very large values of M_2 , because of the correspondingly small $\chi^+ - \chi$ mass difference. This efficiency loss is however partially recovered using techniques such as the tagging of the production of an almost invisible final state by a photon from initial state radiation, or such as the identification of heavy stable charged particles when the $\chi^+ - \chi$ mass difference becomes similar to or smaller than the pion mass [2]. This last configuration is also encountered in models based on anomaly mediated supersymmetry breaking (AMSB).

Light sleptons have a negative impact on the sensitivity of the above searches. The chargino production cross section is reduced, and this is not fully compensated by an increase of the neutralino production. Furthermore, the decay branching ratios are modified, with a larger contribution of the leptonic final states. In particular, invisible final states open up such as $\chi' \rightarrow \tilde{\nu}\nu$, or quasi-invisible ones such as $\chi^+ \rightarrow \ell\tilde{\nu}$ when the $\chi^+ - \tilde{\nu}$ mass difference is very small; the latter configuration has been dubbed “the corridor”. The rescue comes from the direct searches for sleptons. With the assumption of a unified slepton mass m_0 at the GUT scale, a slepton mass limit can be translated into constraints in the (m_0, M_2) plane, for fixed $\tan\beta$. These constraints restrict in turn the allowed sneutrino masses, thus

alleviating the negative impact of the corridor.

The power of the combination of various search channels is even more apparent in the context of the limit which can be set on the mass of the LSP. It should however be emphasized that the results which will be given below are valid only under the assumptions of slepton and gaugino mass unification at the GUT scale. (Indeed, without gaugino mass unification, the neutralino-LSP mass could not be constrained at all by LEP results.) The results are summarized in Fig. 2 [2]. For large slepton masses, the limit on m_χ is about half the chargino mass limit for large $\tan\beta$, somewhat lower otherwise. For low slepton masses, the lowest limit is set at large $\tan\beta$ by selectron searches in the corridor. Finally, Higgs search results are used to constrain the low $\tan\beta$ regime. In the end, the absolute LSP mass limit is 47 GeV.

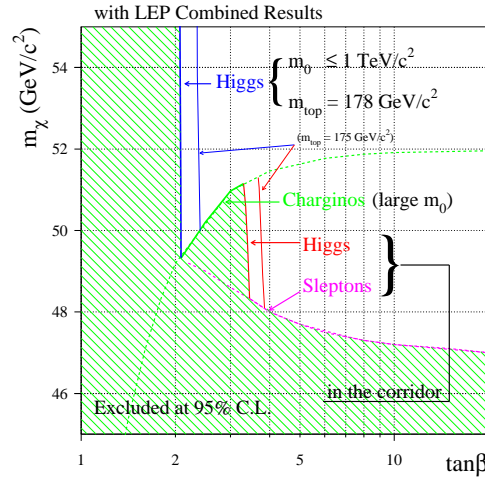


Fig. 2. Limit on the mass of the lightest neutralino, as a function of $\tan\beta$, obtained by the four LEP experiments. From low to high values of $\tan\beta$, the exclusion is given by Higgs boson searches, by chargino searches, by Higgs boson searches in the corridor, by slepton searches in the corridor.

The constraints from Higgs boson searches were obtained as follows: sfermion (slepton and squark) and gaugino mass unifications are assumed; for a choice of m_0 , M_2 and $\tan\beta$, the masses of \tilde{t}_L and \tilde{t}_R are computed, using the renormalization group equations; the mixing in the stop sector is set so as to maximize its impact on the Higgs boson mass; the mass m_A of the pseudoscalar Higgs boson is chosen very large for the same reason; in this configuration, the Higgs boson is standard model-like; if its expected mass m_h is smaller than the combined LEP limit, the set of values considered for m_0 , M_2 and $\tan\beta$ is excluded; a lower limit on M_2 ,

hence on m_χ , is obtained from a scan on M_2 (This limit is tightest for small values of m_0 and $\tan\beta$.); finally, a scan on m_0 allows an absolute χ -mass lower limit to be set for the chosen value of $\tan\beta$. This method relies on the assumption that all m_h values smaller than the LEP limit are excluded. There are however parameter configurations leading to a Higgs boson mass smaller than the LEP limit, and for which the standard model Higgs boson searches are not sensitive (e.g., because of a vanishing branching ratio for $h \rightarrow b\bar{b}$). It has been verified by a fine scan of the parameter space that all these configurations are indeed excluded by searches for supersymmetric particles, for charged or invisible Higgs bosons, for associated hA production, or by flavor independent Higgs boson searches, including dichotomies when appropriate (e.g., if two consecutive parameter sets are excluded by different searches) [4]. In the end, the LEP limit was found to be robust, and hence was appropriately used to set the LSP mass limit. The result was also checked to be unaffected by variations of the top quark mass within its error.

The LSP mass limit was additionally derived within the more constrained mSUGRA framework. It was found to be slightly tighter, at the level of 50 GeV [2].

3 A bit of Gauge Mediated SUSY Breaking

In models based on GMSB, the SUSY breaking scale is much lower than in models based on supergravity, so that the LSP is a very light gravitino \tilde{G} . The phenomenology depends largely on the nature and on the lifetime of the next-to-lightest SUSY particle (NLSP), which is a slepton (preferentially a stau) or the lightest neutralino χ .

Pair production of stau-NLSP's has been searched by the four LEP experiments. Each stau decays to a τ and a gravitino, which can be considered massless for practical purposes. Depending on the stau lifetime, the final state evolves from a pair of acoplanar taus, for which the standard SUSY search applies, to a pair of stable massive charged particles. For intermediate lifetimes, dedicated searches for tracks with a large impact parameter or exhibiting a distinct kink were performed. In the end, stau-NLSP's lighter than 87 GeV are excluded, independent of the stau lifetime [2].

The pair production of χ -NLSP's leads at LEP to a final state consisting of an acoplanar photon pair ($\chi \rightarrow \tilde{G}\gamma$). No such signal was observed, leading to the exclusion of the domain shown in yellow in Fig. 3 [2]. For light selectrons, χ masses as high as 100 GeV are excluded, which rules out the GMSB interpretation of a suggestive event observed by CDF in the Run I of the Tevatron, and containing two energetic electrons, two high energy photons, and a large missing transverse energy.

Searches for GMSB with a χ -NLSP have been performed by both CDF and DØ in approximately 200 and 260 pb^{-1} of Run II Tevatron data, respectively. These are inclusive searches for topologies involving two photons and large missing transverse energy \cancel{E}_T . After mild quality and topological cuts, the main backgrounds remaining are due to

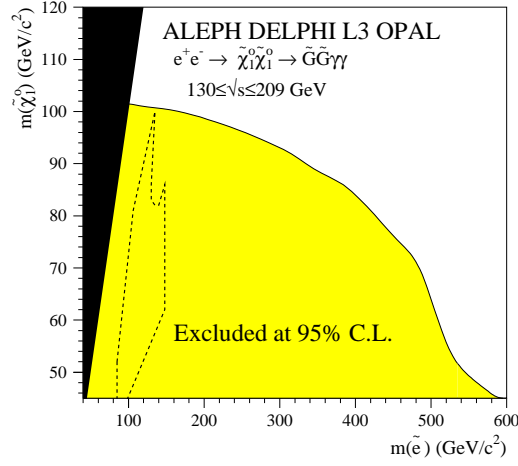


Fig. 3. Domain excluded by the four LEP experiments in the plane $(m_{\tilde{e}}, m_{\chi})$, in GMSB with a neutralino NLSP (prompt $\chi \rightarrow \tilde{G}\gamma$ decays). The region compatible with the kinematics of the “CDF event” is seen to be excluded.

- jets with a large electromagnetic component, thus faking photons, and to the QCD production of a photon and such a jet (or of two photons). Here the missing E_T is due to mismeasurements;
- events containing real \cancel{E}_T , with an electron falsely identified as a photon, e.g. because the associated charged track was not reconstructed.

Both types of background are determined from the data. For the first one, events with reversed photon quality cuts are used to determine the shape of the \cancel{E}_T distribution, which is then normalized to the diphoton sample at small \cancel{E}_T values. The background with real electrons is evaluated requiring that one of the would be photons is actually matched to a reconstructed track, and folding in the track reconstruction and matching inefficiencies. The photon p_T cuts are set to 13 and 20 GeV in CDF and DØ, respectively. The resulting missing E_T distribution obtained by CDF is shown in Fig. 4(left), together with the various background contributions [5]. Optimal cuts on \cancel{E}_T are next applied, 45 GeV in CDF and 40 GeV in DØ, leading to 0 and 2 events observed, respectively; the corresponding standard model expectations are 0.6 and 3.7 events.

The interpretation of these results is performed within the minimal version of GMSB, with the following choice of parameters: one set of messengers; the messenger mass equal to twice the effective SUSY-breaking scale Λ ; μ positive; and $\tan\beta = 15$. (This set corresponds to the so-called “Snowmass slope”). For such parameter choices, the dominant mechanisms are chargino pair and associated chargino-second neutralino productions. The comparison of the cross section ex-

cluded by DØ with the predictions of this model is shown in Fig. 4(right) [6]. It can be seen that Λ values smaller than ~ 80 TeV are excluded, which corresponds to a lower limit of 108 GeV for the mass of the lightest neutralino, which is currently the world's most constraining result.

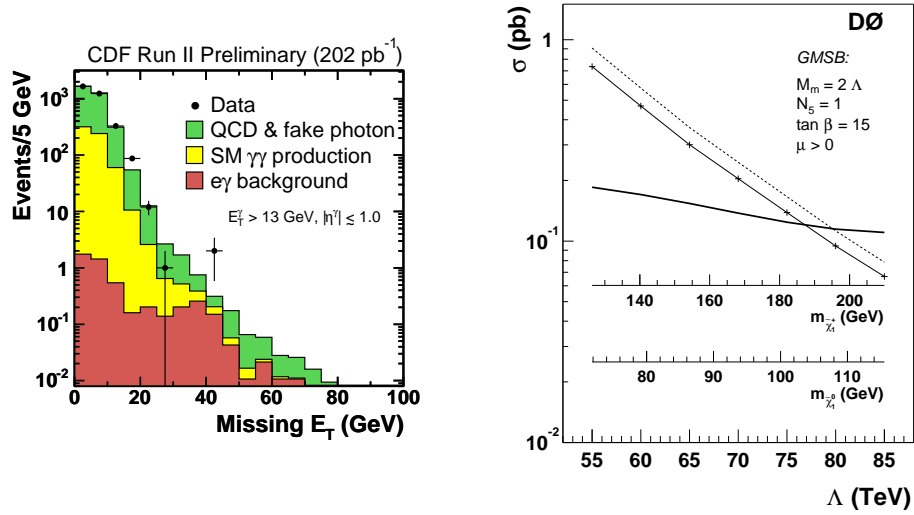


Fig. 4. Tevatron searches for GMSB with a neutralino NLSP: the missing E_T distribution obtained by the CDF experiment in events containing two high E_T photons, with the various background contributions indicated (left); the cross-section upper limit set by the DØ experiment, as a function of the effective SUSY-breaking scale Λ and of the χ mass, compared to a theoretical expectation (thin dashed line) as detailed in the text (right).

4 SUSY trileptons at the Tevatron

The cleanest signature for SUSY at the Tevatron is expected to arise from associated chargino-second neutralino production, $p\bar{p} \rightarrow \chi^+\chi'$, followed by leptonic decays, $\chi^+ \rightarrow \chi^{\ell^+}\nu$ and $\chi' \rightarrow \chi^{\ell^+}\ell^-$, in which case the final state contains three leptons and missing E_T . The drawbacks are that the cross sections (times branching ratios) are rather small, that the final state leptons have soft spectra, and that final states containing τ 's can be enhanced, in particular at large $\tan\beta$. A large integrated luminosity is therefore needed, and various trilepton final states have to be combined to increase the search sensitivity.

The DØ collaboration has investigated trilepton topologies in 145 to 250 pb^{-1} of Run II data, depending on the final state analysed. The signatures considered up to now were $e\ell\ell$, $e\mu\ell$, $\mu\mu\ell$ and same sign dimuons, where the third lepton ℓ is not required to be positively identified, which increases the efficiency for final states

involving τ 's. The analysis was optimized for chargino and neutralino masses just beyond the LEP limits, and for slepton masses just above the χ' mass in order to enhance leptonic branching ratios. The mSUGRA framework (with $\tan\beta = 3$, $A_0 = 0$ and $\mu > 0$) was used to make definite predictions, but the results are expected to hold more generally in the MSSM when the mass hierarchy $m_{\chi^+} \sim m_{\chi'} \sim 2m_\chi \sim m_{\tilde{e}}$ is preserved.

The selections require two identified, possibly rather soft, isolated leptons (electrons or muons), some significant missing E_T , and reject events where a pair of opposite sign electrons or muons is compatible with originating from a Z -boson decay. Backgrounds are further reduced by the requirements of either a same sign for two muons, or of the presence of an additional isolated charged particle track (the "third" lepton). Backgrounds originating from WW , WZ and $W\gamma$ (where the photon converts into an e^+e^- pair in the detector) are estimated by simulation, while the background from $b\bar{b}$ production, which may lead to moderately isolated muons, is determined using data. In the end, three candidate events are selected, while the expected background amounts to 2.9 ± 0.8 events. This result translates into an upper limit for the product of the production cross section by the leptonic branching ratio, as shown in Fig. 5 [6]. The improvement over the DØ Run I result is quite substantial, but not yet sufficient to reach the level of the mSUGRA prediction. An increased integrated luminosity and the inclusion of a search for same sign electron pairs should allow mSUGRA territory to be entered in the near future.

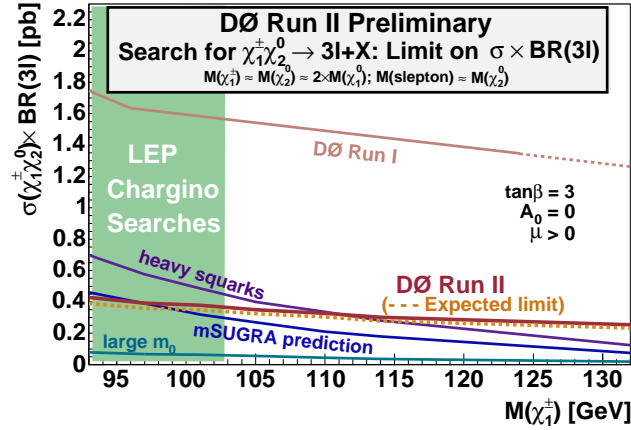


Fig. 5. Upper limit on the product of cross section and branching ratio into three leptons obtained by the DØ experiment, as a function of the chargino mass. The results are compared to an mSUGRA theoretical prediction. The region excluded by the LEP chargino searches is also shown.

5 Squarks and gluinos at the Tevatron

The CDF collaboration has performed a search for stable massive charged particles in 53 pb^{-1} of Run II data. Such particles are expected to behave like slow moving heavy muons in the detector, and can be identified using a time of flight technique. The null result, interpreted in terms of absence of stable stop production, leads to mass lower limits of 108 GeV if such stable stops appear isolated, and of 95 GeV otherwise [5].

For large values of $\tan\beta$, mixing is large in the sbottom sector, and the mass hierarchy could well be such that gluinos are abundantly produced, and always decay into a $b\bar{b}$ pair. A light sbottom is expected to decay according to $\tilde{b} \rightarrow b\chi$, so that the final state resulting from gluino pair production would contain four b quarks and exhibit missing E_T . The CDF collaboration has searched for this topology in 156 pb^{-1} of Run II data, requiring one or two of the four jets to be b -tagged. The second option gives the best sensitivity, and typically allows gluinos with masses up to 280 GeV to be excluded for sbottom masses smaller than 240 GeV (and for $m_\chi = 60 \text{ GeV}$), within the specific theoretical framework considered (Fig. 6) [5].

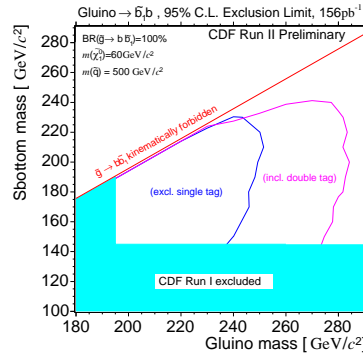


Fig. 6. Domain excluded by the CDF collaboration in the plane $(m_{\tilde{g}}, m_{\tilde{b}})$, for light gluinos and sbottom quarks, and for $m_\chi = 60 \text{ GeV}$.

Generic squark production has been investigated by the DØ collaboration, using 85 pb^{-1} of Run II data. If squarks are lighter than gluinos, they are expected to decay according to $\tilde{q} \rightarrow q\chi$, in which case the final state arising from squark pair production is a pair of acoplanar jets. Other squark “cascade” decay modes may however spoil this topology, such as $\tilde{q} \rightarrow q\chi'$ or $q'\chi^\pm$. Since the decay branching ratios are model dependent, the mSUGRA framework was used to conduct the analysis, with $\tan\beta = 3$, $A_0 = 0$, and $\mu < 0$. The model line $m_0 = 25 \text{ GeV}$ was chosen so as to lead to squarks essentially as light as possible, and the only free parameter is therefore M_2 , which controls simultaneously the squark and gluino masses.

The main selection cuts were designed to select pairs of acoplanar jets while rejecting as much as possible of the main backgrounds: multijet production from standard QCD processes, with jet energy mismeasurements creating fake \cancel{E}_T ; and associated production of a W boson and jets, with $W \rightarrow \ell\nu$. The associated production of a Z boson and two jets causes an irreducible background when the Z decays into a $\nu\bar{\nu}$ pair. Two high p_T jets were required and a veto against isolated leptons was applied. The missing E_T was required not to be directed along (or opposite to) any jet. The final cuts at 275 GeV on the sum H_T of all jet transverse energies and at 175 GeV on the missing E_T were optimized to give the smallest signal production cross section expected to be excluded at the edge of the Run I exclusion domain. The missing E_T distribution is shown in Fig. 7(left). It can be seen that the QCD background, clearly visible at low \cancel{E}_T , is negligible beyond the chosen \cancel{E}_T cut value. Four events were selected in the data, while $(2.7^{+2.3}_{-1.5})$ are expected from standard model processes, mostly from $Z \rightarrow \nu\bar{\nu}$ and from $W \rightarrow \tau\nu$. The highest \cancel{E}_T event is shown in Fig. 7(right). Along the model line chosen, squark masses smaller than 292 GeV are excluded (assuming four mass-degenerate squark species), as well as gluino masses up to 333 GeV [6]. These results slightly improve on those obtained at Run I.

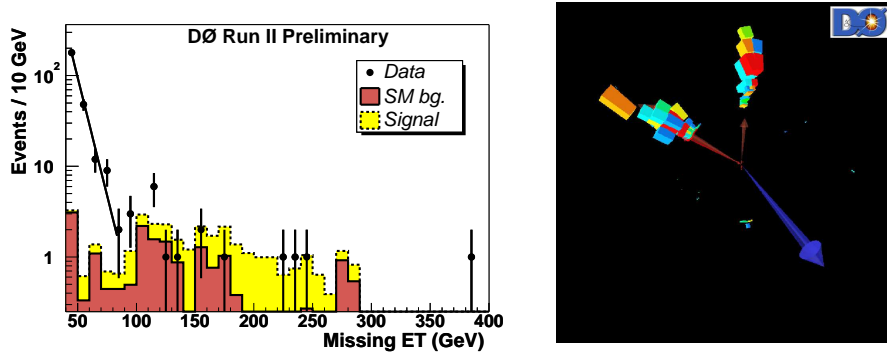


Fig. 7. Search for generic squarks by the DØ collaboration: the final missing E_T distribution (left), with the contributions from standard model processes (brown), from QCD (exponential fit), and expected from the signal (yellow, on top of standard model); three-dimensional view of the highest missing E_T event (right).

The question can be raised of the relevance of the Tevatron searches for squarks and gluinos. Indeed, if gaugino mass unification is assumed, as it is the case in mSUGRA, the LEP limits on charginos translate into gluino mass limits well beyond those within the Tevatron reach. Similarly, if slepton and squark mass unification is assumed, the LEP limits on selectrons are more restrictive than those on squark masses from the Tevatron. The CDF and DØ collaborations should therefore be encouraged to present their results within frameworks other than mSUGRA. For

instance, in SUSY-GUT models where SUSY breaking is induced by an F-term which is a **75** of SU(5), rather than by a singlet, the M_3/M_2 ratio is of order unity, in which case LEP results do not constrain gluino masses above 105 GeV or so. String inspired models can also lead to similar gaugino mass hierarchies.

6 Conclusions

Before concluding, I want to quote a result which is a bit off the main track, but still relevant for supersymmetry. The CDF and DØ collaborations have searched for the rare decay $B_s \rightarrow \mu^+ \mu^-$ which is expected to be at the $3.5 \cdot 10^{-9}$ level in the standard model, but may be enhanced by a factor of $(\tan \beta)^6$, i.e., by as much as three orders of magnitude, in supersymmetry. At the time this talk was given, the CDF collaboration had quoted a limit of $7.5 \cdot 10^{-7}$ [5], improving substantially over the previous best limit and probing relevant new territory, while the DØ collaboration had not yet “opened the box”.¹⁾

As of today, the main constraints on supersymmetry obtained at accelerators remain those established by LEP. If fine tuned parameter configurations are discarded, limits of the order of 100 GeV are set on slepton and chargino masses, and the mass of the lightest supersymmetric particle has to exceed 47 GeV in the MSSM with slepton, squark and gaugino mass unification.

The Tevatron is however already providing relevant results. In the framework of gauge mediated supersymmetry, a lower limit of 108 GeV has been set on the mass of a neutralino NLSP. Trilepton searches should lead to new constraints on minimal supergravity in the near future. Squark and gluino searches are well underway, although an adequate interpretation of the results is still lacking. With the continuously improving performance of the Tevatron, the coming years can be expected to provide an exciting harvest of new results.

References

- [1] Sabine Kraml, these proceedings.
- [2] The LEP-SUSY working group:
<http://lepsusy.web.cern.ch/lepsusy/>
- [3] ALEPH Collaboration, Phys. Lett. **B488** (2000) 234.
- [4] ALEPH Collaboration, Phys. Lett., **B440** (1998) 419,
and Eur. Phys. J., **C17** (2000) 223.
- [5] The CDF Exotics Group:
<http://www-cdf.fnal.gov/physics/exotic/exotic.html>
- [6] DØ New Phenomena Results:
<http://www-d0.fnal.gov/Run2Physics/WWW/results/NP/np.htm>
- [7] DØ B Physics Results:
<http://www-d0.fnal.gov/Run2Physics/WWW/results/B/b.htm>

¹⁾ Since then, the box has been opened, and a limit of $5.0 \cdot 10^{-7}$ has been set [7]